MINIMIZING PARTICLE CONTAMINATION OF NXE3100 RETICLES

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[B] *NANOMETRICS*

OUTLINE

Introduction: ADT learning

Installed infrastructure

Monitoring NXE3100 reticles

- Back-side
- Front-side

EUV pod related

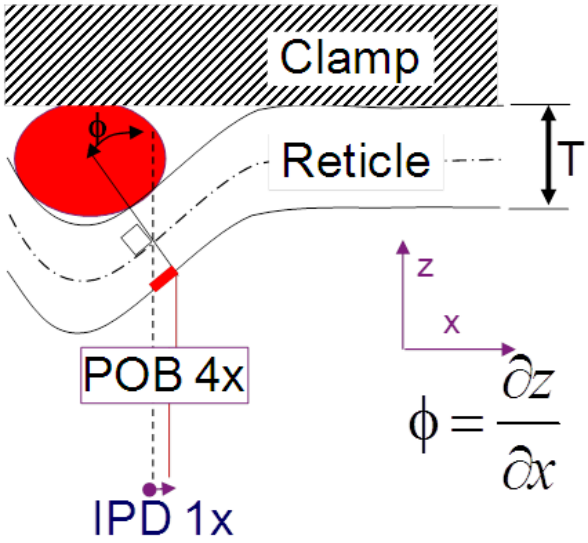
Conclusions

ISSUES OF PARTICLE CONTAMINATION

EUV reticles presently have **no pellicle**
→**Front-side particles** can print (= cause CD change)

Back-side particles can distort the clamped reticle, causing focus and overlay error

+ they can migrate to the reticle clamp and cause similar problems for all subsequent reticles



$IPD = M \cdot \frac{1}{2}T \cdot \phi; M = \frac{1}{4}$

$IPD \approx 0.8 \cdot \phi$

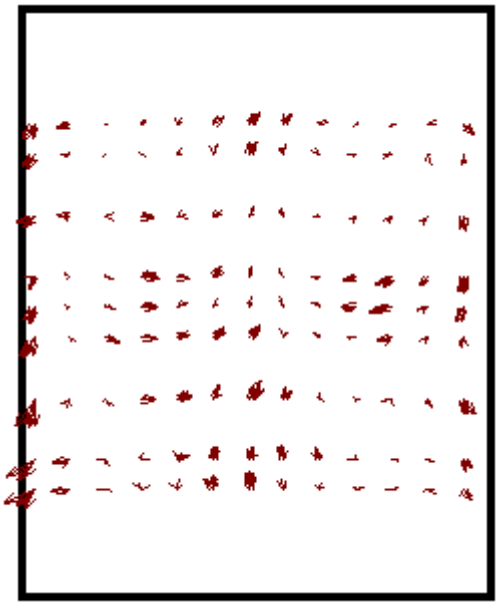
A backside particle is potentially overlay critical if several µm high

(its impact depends on its properties)

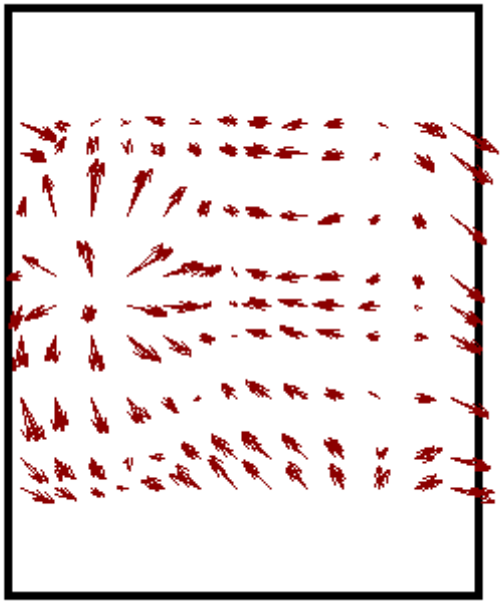
BACK-SIDE PARTICLES CAUSE OVERLAY ISSUES

ADT

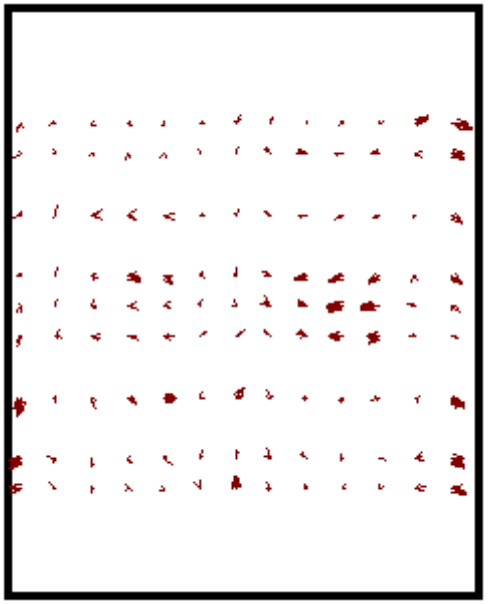
Reference data



Particle on clamp



After clamp cleaning



Recovering required manual clean of reticle clamp.

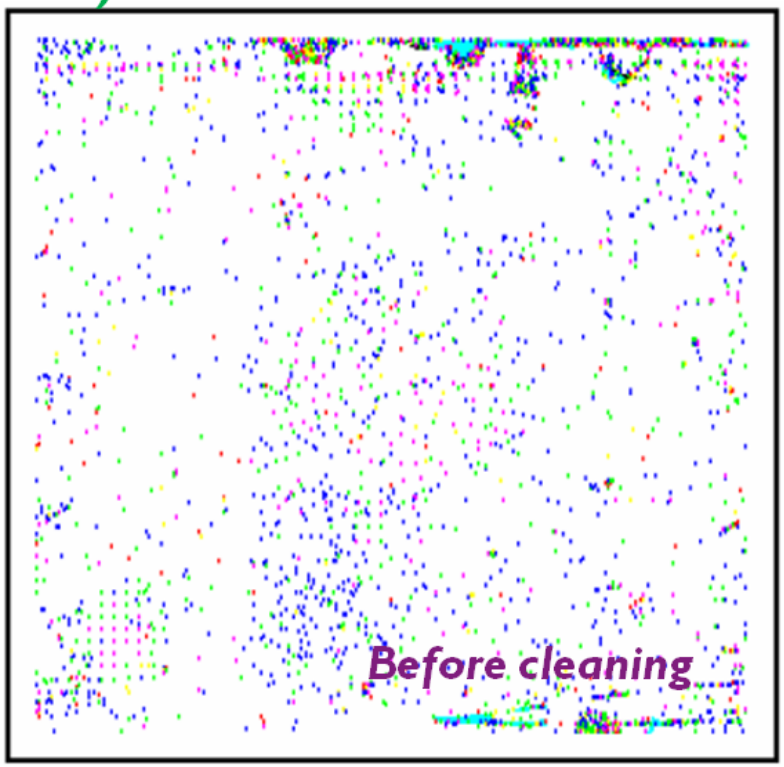
Originally it was the main reason why imec installed a mask cleaner (HamaTech* MaskTrack *Pro*): **AVOIDANCE**

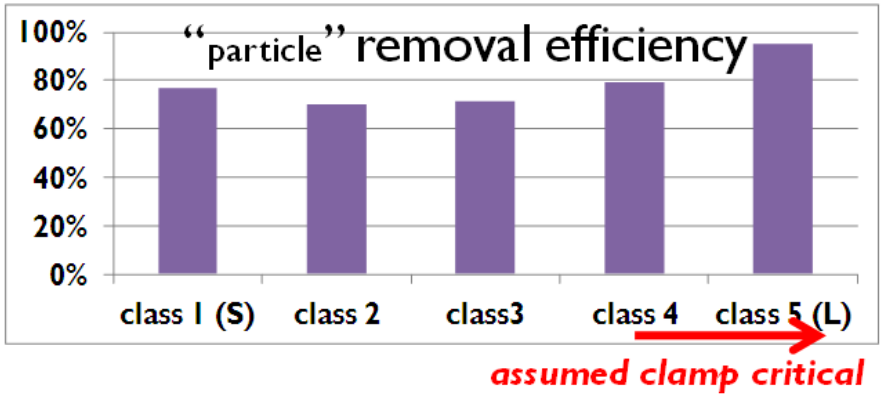
* *Now Suss MicroTec*

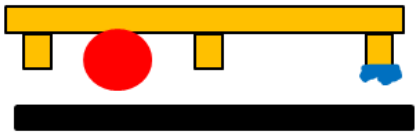
BACKSIDE CLEANING

ADT

(1x clean)







Clamping artifacts may NOT be cleanable

LEARNING CURVE FOR EUV RETICLE HANDLING

GOAL: reduction of particle adders caused by ...

ADT situation before MT-Pro

Mask shop → Shipping box ↔ Manual loading ↔ SB ↔ ADT

- Mask not cleaned
- Shipping
- Manual handling
- SB not cleanable

ADT situation with MT-Pro

Mask shop → Shipping box ↔ Manual loading ↔ SB ↔ MT-Pro (Mask cleaned) ↔ SB ↔ ADT

- Shipping
- Manual handling
- *SB not cleanable*

Present situation for NXE3100 environment

Mask shop → 

→ MT-Pro ↔ 

(Type A) ↔ NXE

- (Almost) free of manual reticle handling
- Cleanable EUV pod

***Target* situation for NXE3100 environment**

Mask shop → 

("Type B" ?) → MT-Pro ↔ 

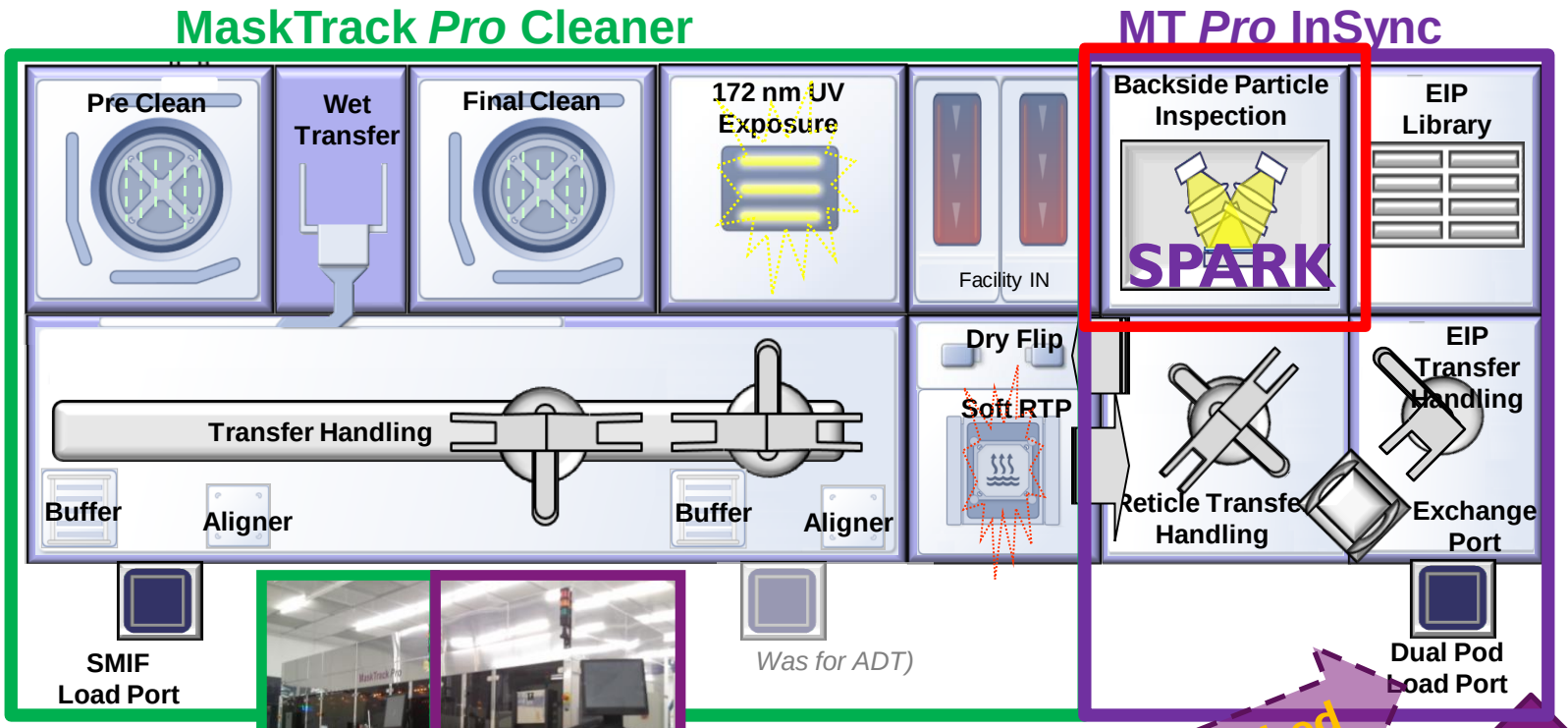
(Type A ?) ↔ NXE

1) ("Type B" ?)
2) one universal EUV pod

- Free of manual reticle handling
- Cleanable EUV pod

Note: Type A vs. B see SEMI E152

UNIQUE INFRASTRUCTURE REALIZED
INTEGRATING CLEANING, BACK-SIDE INSPECTION AND AUTOMATED HANDLING OF NXE3100 RETICLES



RSP200

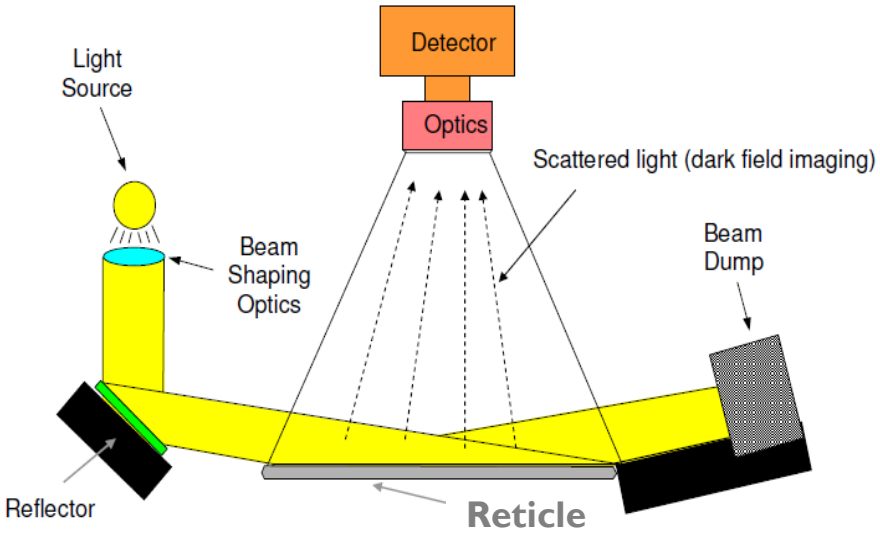
Mask shop

Shippable EUV POD to be established

EUV POD Type A

NXE3100

RETICLE BACK-SIDE INSPECTION



Darkfield full substrate imaging technology

Nanda Tech → nanometrics

SPARK-RIM

Typical Performance

Particle detection size	150nm (via PSL)
Routine use (back-side)	>95% capture rate >250nm
Defect size repeatability	>90%
Measurement time	< 5min
Defect detection on front-side	Empty areas, needs dedicated calibration

Assignment of a size to a detection is based on the intensity of the scattered light! DISCLAIMER: Calibration done for PSL. Mind that the sizing accuracy for an arbitrary "defect" with a given shape and morphology may be limited.

OUR TARGET SCENARIO FOR MASK HANDLING

New NXE3100 reticles

- Receive the reticle in EUV pod.
- Inspect reticle back-side on SPARK.
- Evaluate inspection results against practical target "OK for NXE3100"
  - If OK: Reticle in Type A EUV Pod can be moved to Scanner
  - If not OK: Clean reticle to reach OK status (+ follow-up if not possible)
- Reticle mates with fixed EUV pod.

Routine check of NXE3100 reticles in use (particle monitoring)

- Same way, automated, via its EUV pod Type A in use on the NXE3100

All via fully automated handling within MT *Pro* + InSync

OUR PRESENT SCENARIO FOR MASK HANDLING

New NXE3100 reticles

- The reticle is received from the mask shop in ...
  - ... shipping box: manual load into RSP200, auto transfer into EUV pod on InSync
  - ... RSP200: auto transfer into EUV pod on InSync
  - ... EUV pod: so far it was not yet fully considered shippable
- Reticle back-side is inspected on SPARK.
- Evaluate inspection results against practical target "OK for NXE3100"
  → Still operator decision (inspired by # detections)
- Reticle mates with fixed EUV pod.

Routine check of NXE3100 reticles in use (particle monitoring)

- Same way, automated, via its EUV pod Type A in use on the NXE3100

All via fully automated handling within MT *Pro* + InSync

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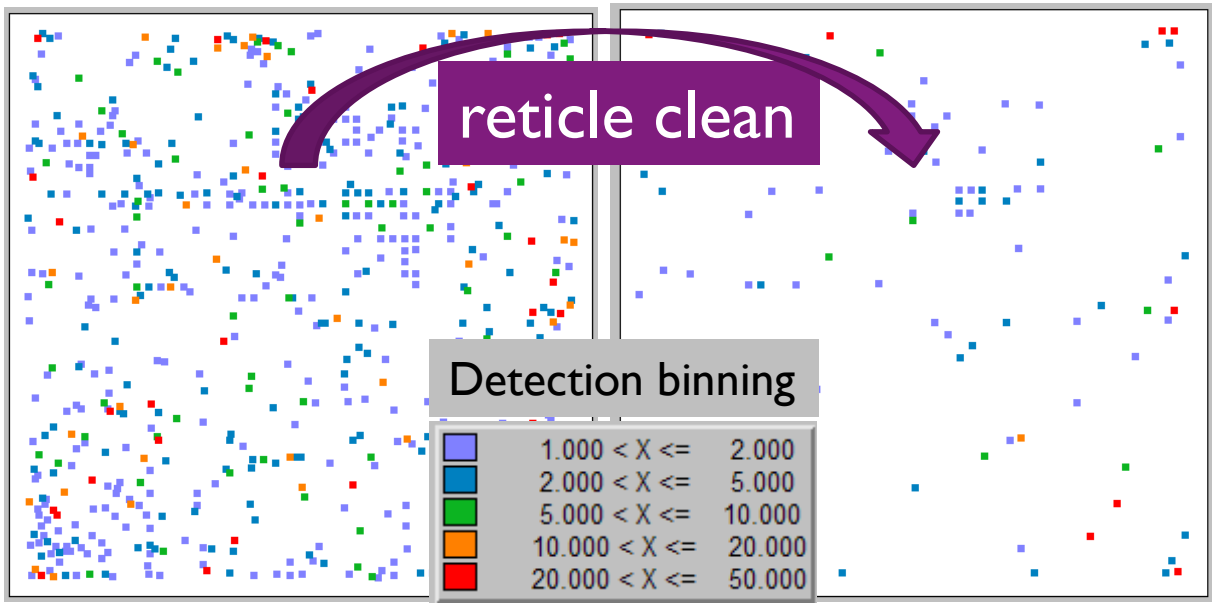
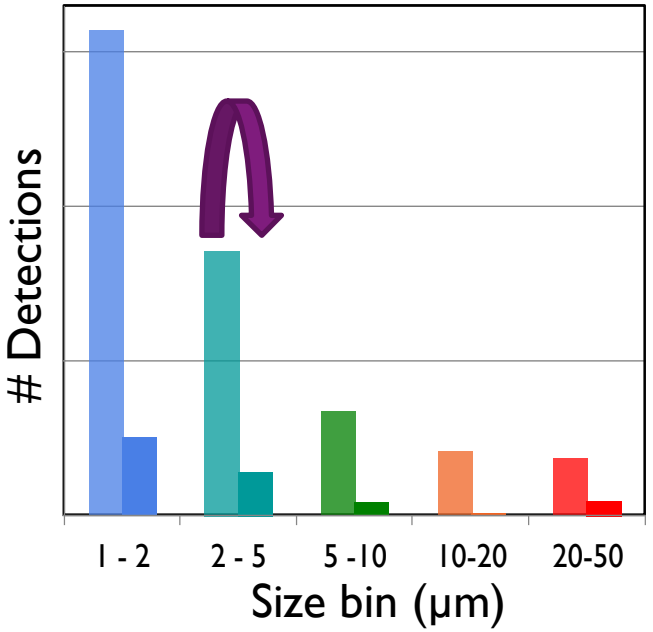
Conclusions

BACK-SIDE INSPECTION BY SPARK

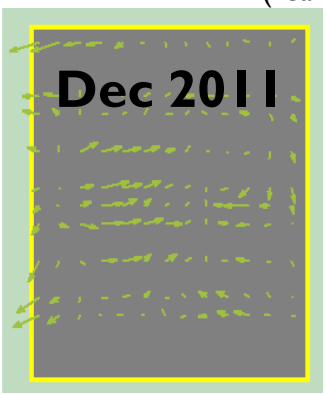
EXAMPLE 1: OUR NXE3100 MONITOR RETICLE

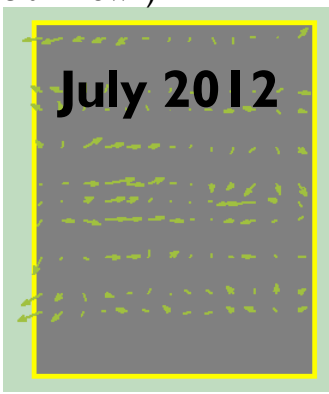




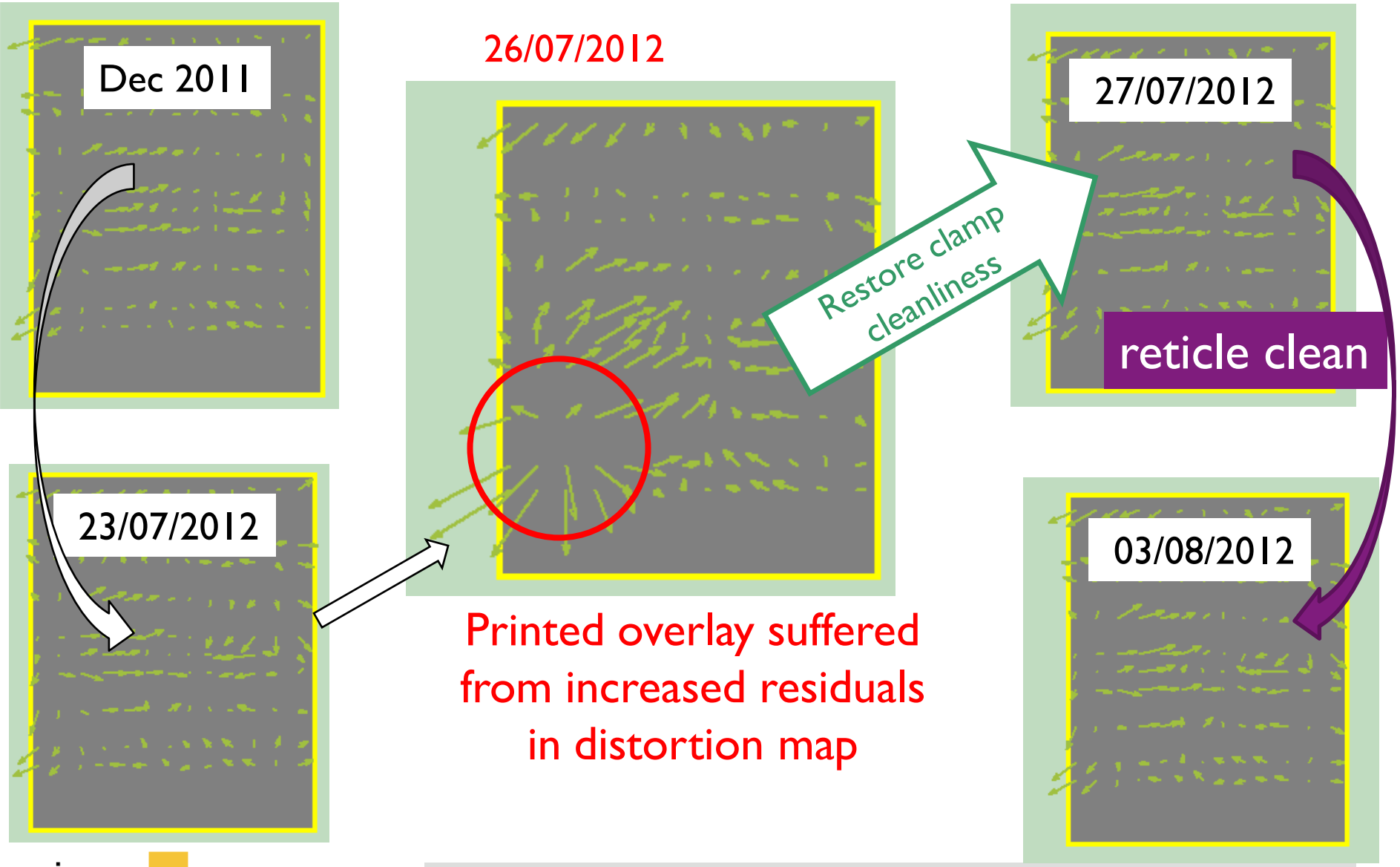
Only detections > 1µm shown
Reminder: size of DETECTION
(real size unknown)

- Monitor reticle used 2-3x/week
- It has **several detections >1um**
- Many cleanable,
  yet some cleaning-resistant *(clamping artifacts ?)*.
- Yet, the reticle gives persistent **good overlay**.

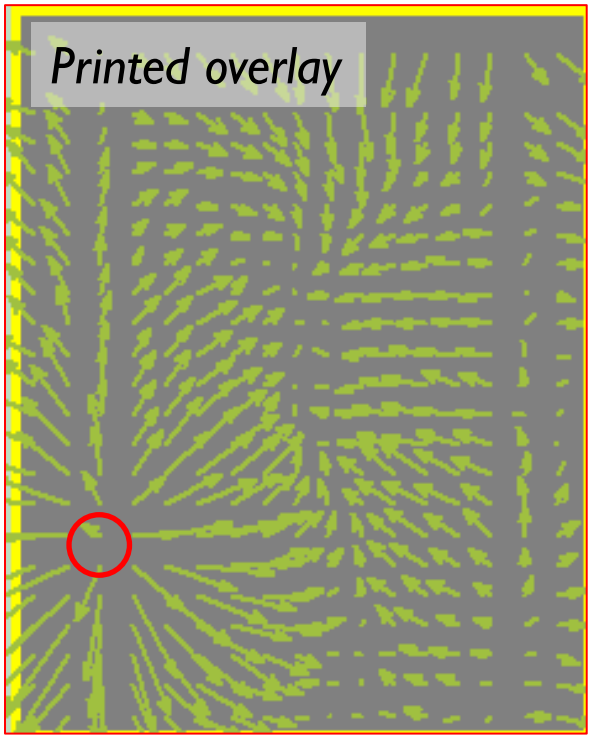


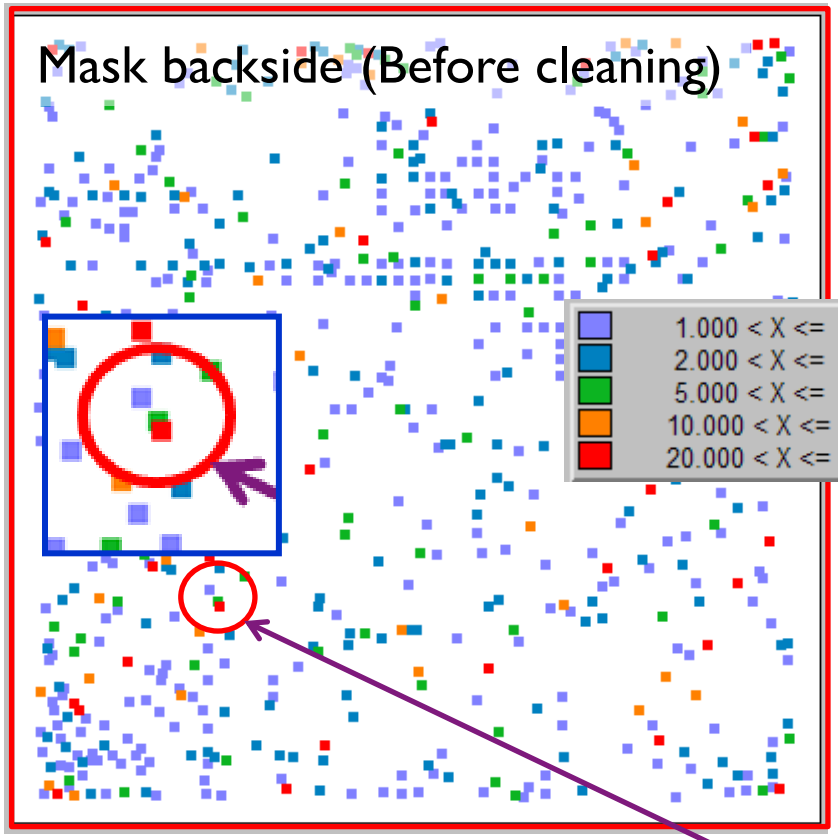


SUDDEN OVERLAY EXCURSION



SUDDEN OVERLAY EXCURSION
FOUND DUE TO PARTICLE ON RETICLE CLAMP



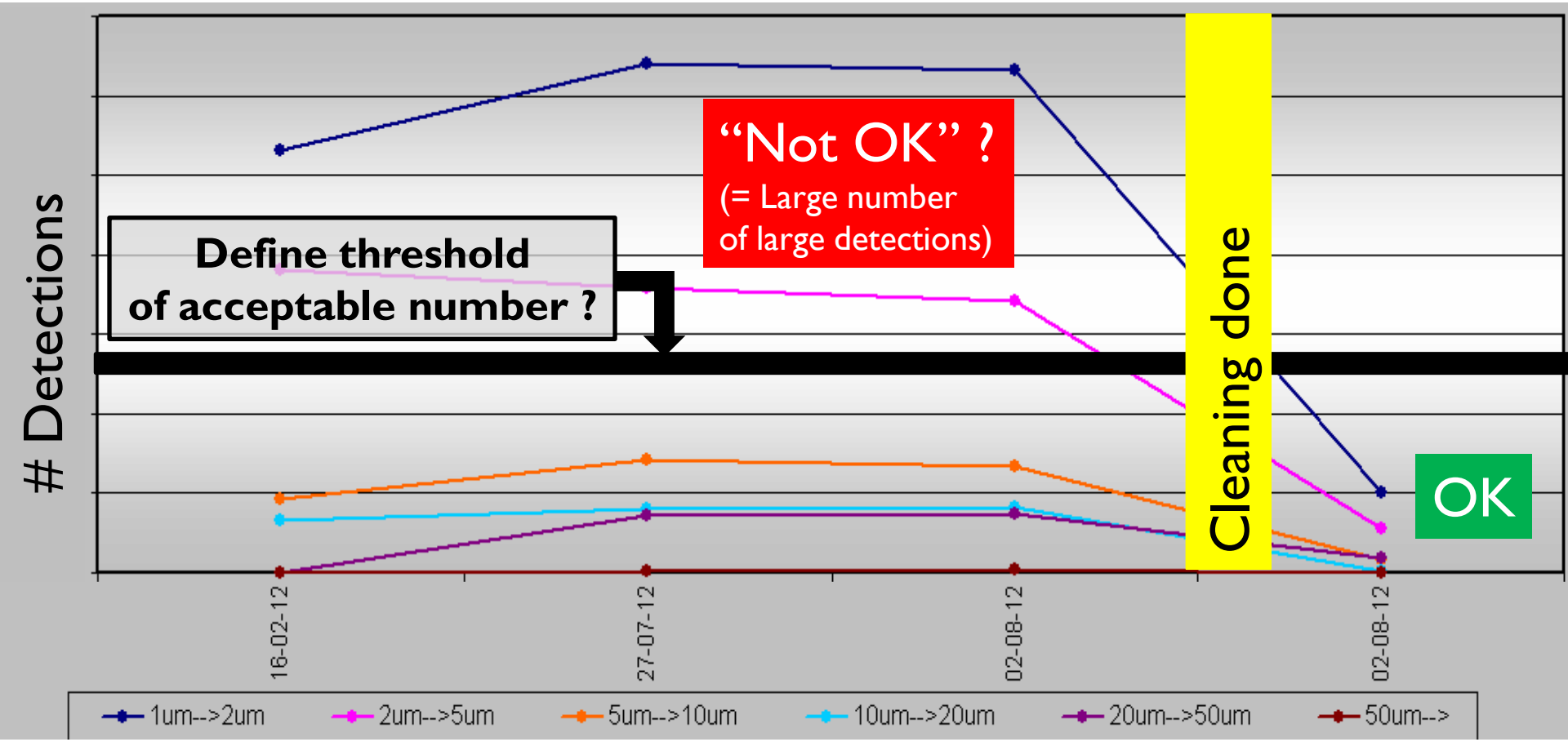


Printed overlay correlates to SPARK measurements *(residual)*.
Origin of this overlay killing particle unknown.
Could not yet AVOID particle on clamp by monitoring.
Recovered from bad overlay via clamp clean by "stamping".

3 Detections:
1, 6 and 26 µm.
But all reduced to sub-critical by reticle clean.

BACKSIDE MONITORING

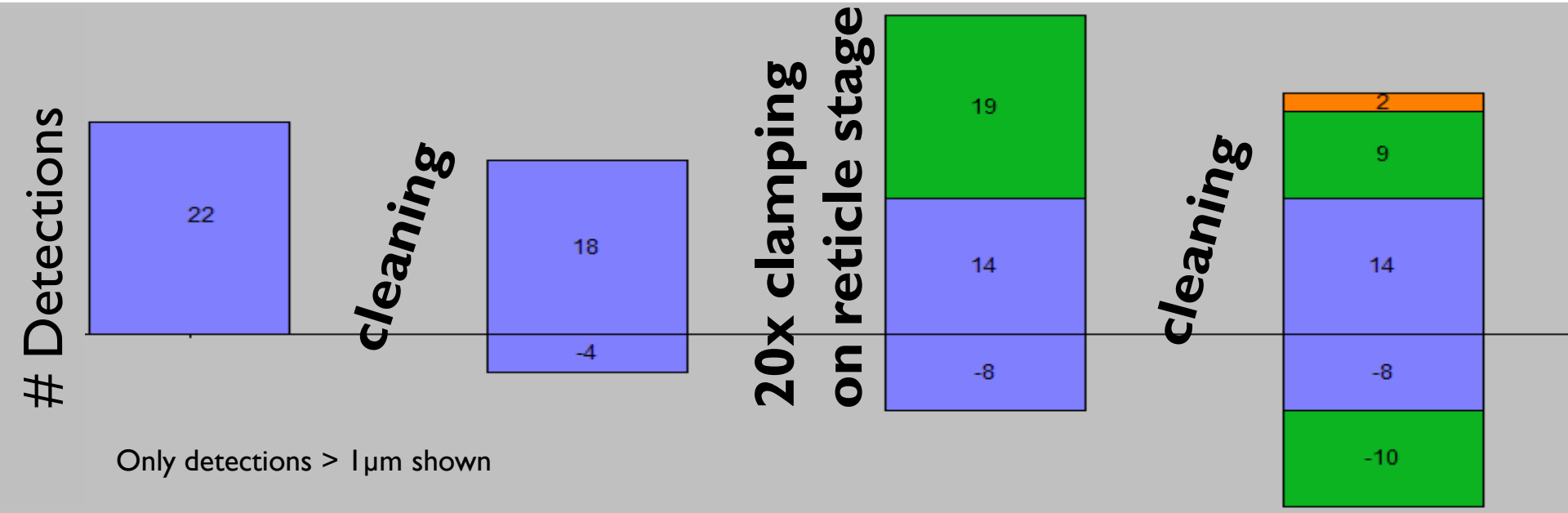
NXE3100 MONITOR RETICLE

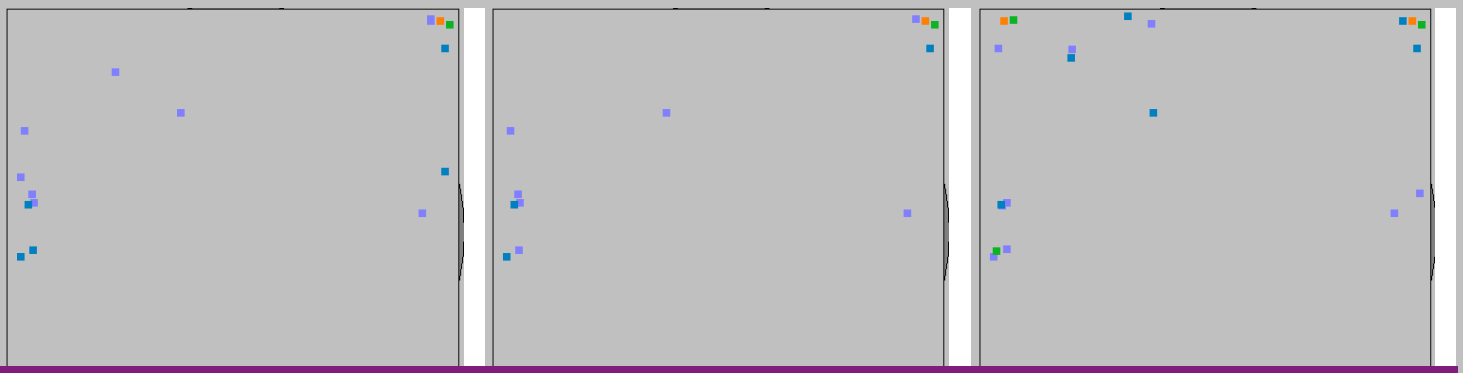


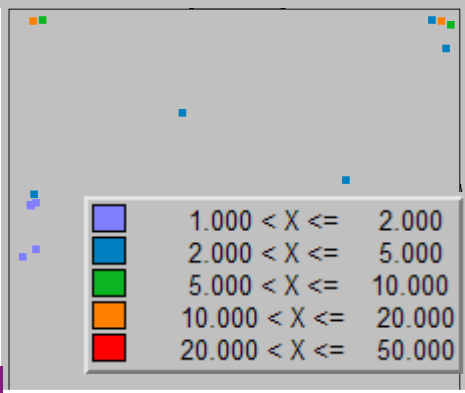
Number of large detections not really feasible as criterion.
Size binning has no info on height:
How interpret if overlay sensitive ?

BACK-SIDE INSPECTION,

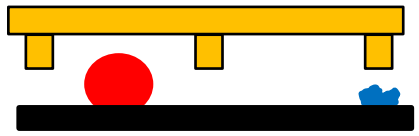
EXAMPLE 2: RETICLE WITH LOADING HISTORY





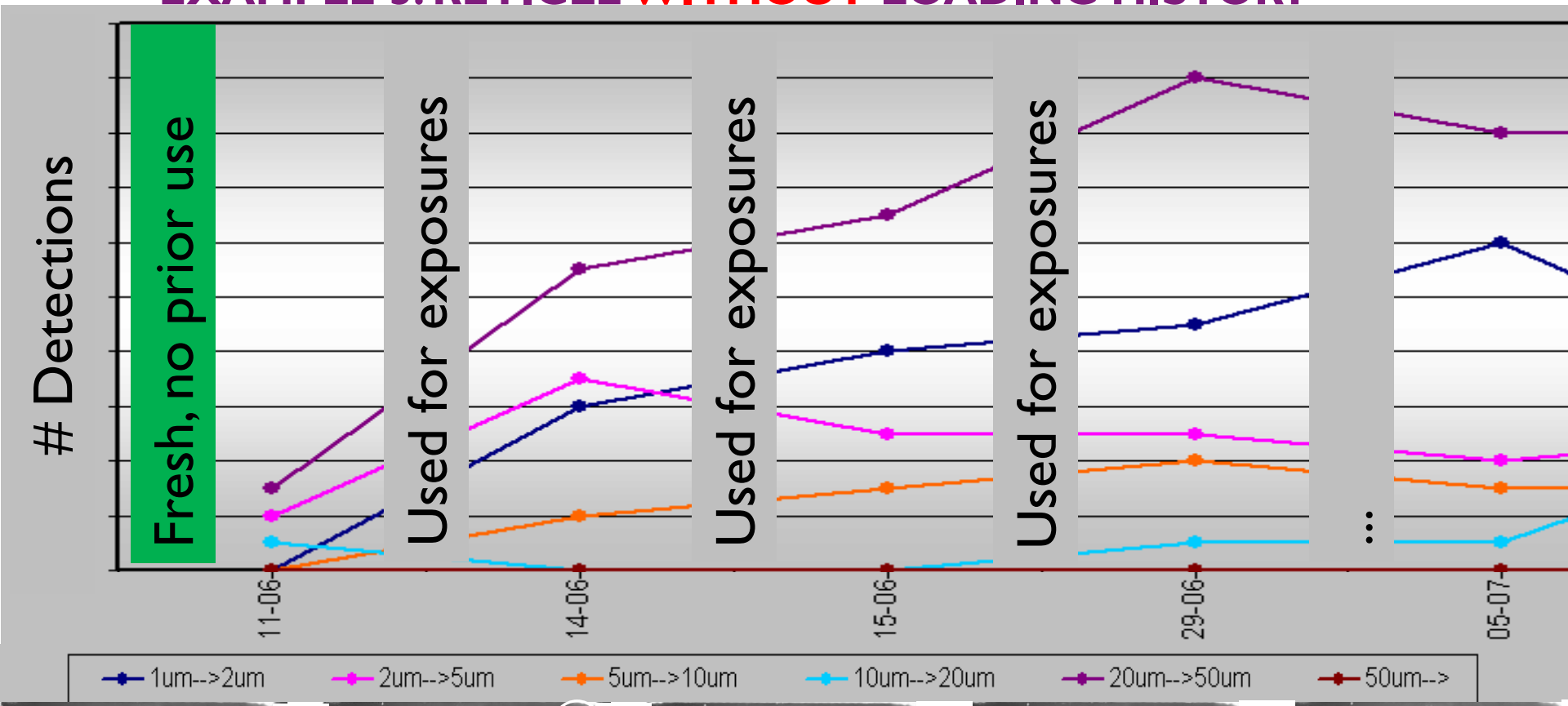


Need way to differentiate between chuck artifacts and (potentially) overlay-critical particles.



BACK-SIDE INSPECTION,

EXAMPLE 3: RETICLE WITHOUT LOADING HISTORY



Target of monitoring is to flag
potentially overlay-critical particle adders.

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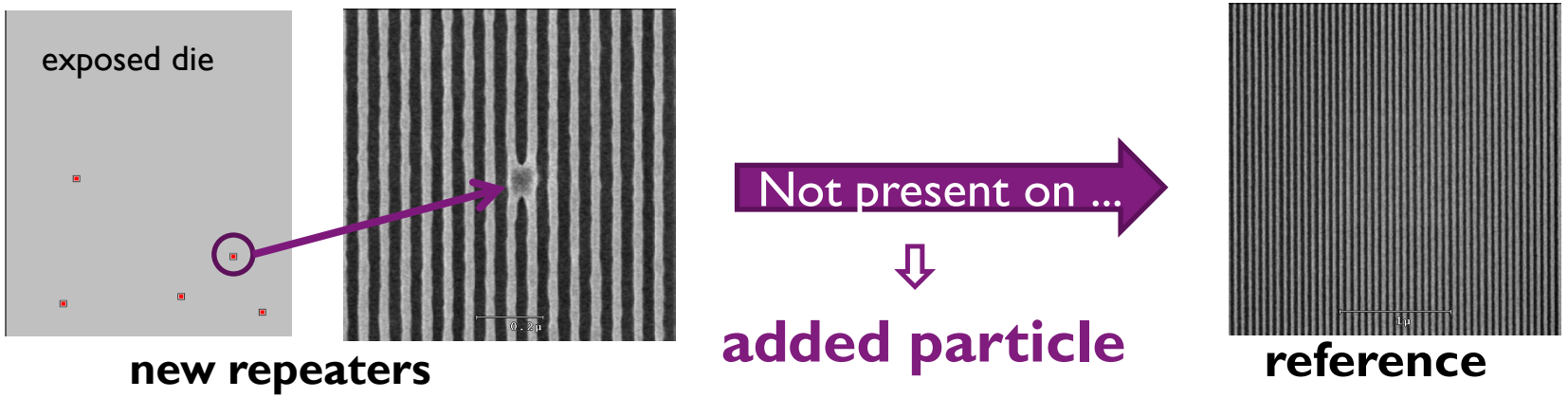
MONITORING FOR FRONT-SIDE ADDERS

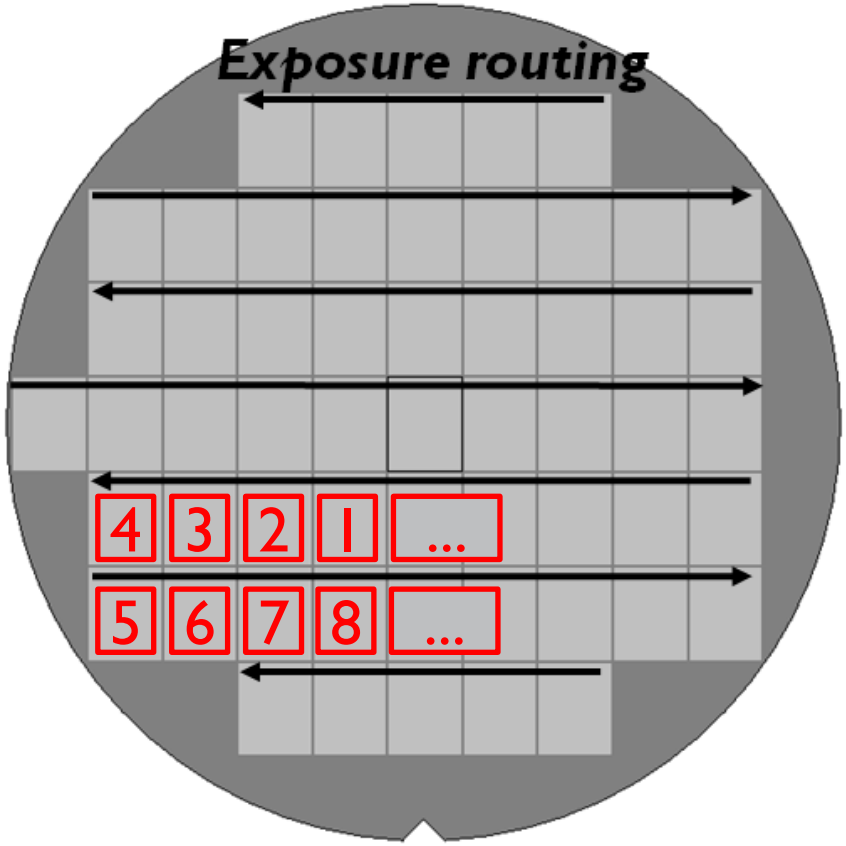
- Evaluation by ***wafer printing*** + wafer inspection + repeater analysis
  - Estimated capability for particles/defects >~60 nm
  - Note: at 32nm l/s: ~30nm would be printable (= causing >10% CD change)
- Procedure:
  - Keep **reference wafer**, exposed when reticle was new(er)
  - After additional use of the reticle, expose a **new wafer with multiple dies**
  - Via wafer inspection check for repeating defects across multiple dies
  - Upon **finding new repeaters** check on reference exposure whether it was already there (but possibly missed by wafer inspection)
  - Absence on the reference wafer **confirms it is new adder** on the reticle

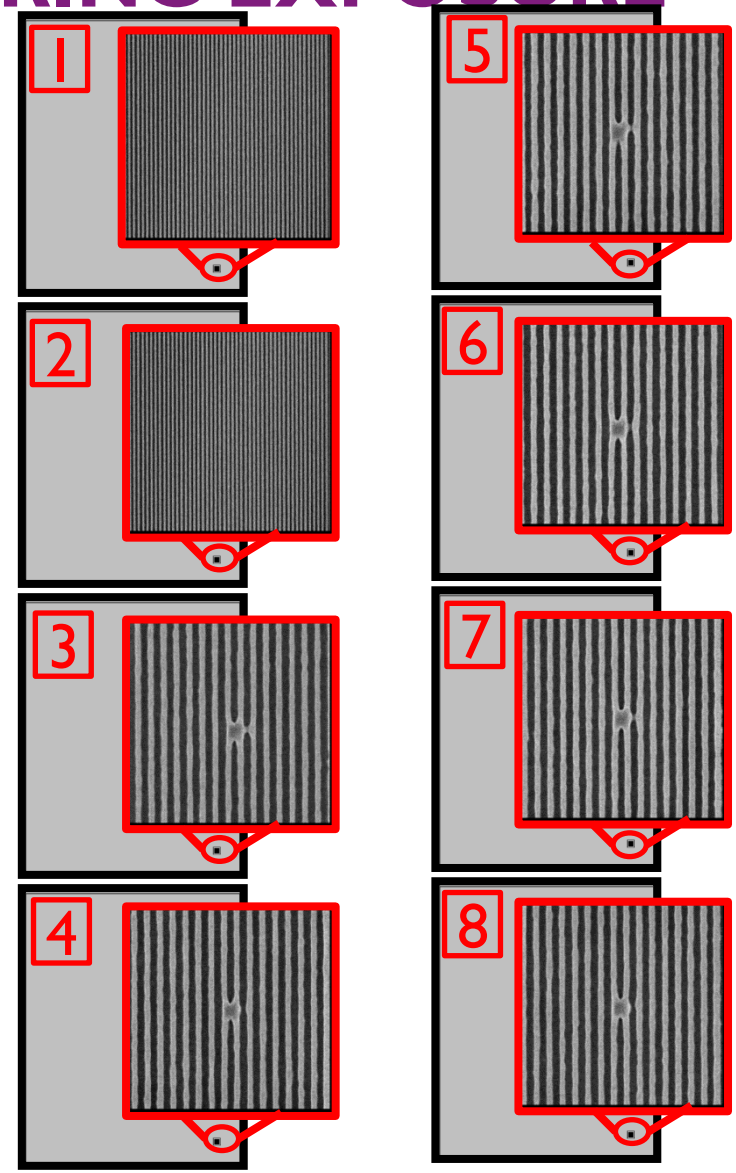


Has been very valuable in the past to identify adders by handling (manual transfer, shipping, ...)

FRONT-SIDE ADDERS DURING EXPOSURE

After minimizing adders related to handling in the fab, the **technique reveals also other adder contributors**: inside the scanner (reminder: pellicle-less is EUV specific)





Note: imec's NXE3100 does not include all ASML's latest mitigation techniques

EUV POD RELATED...

EUV pod **status**

- So far only **Entregris pods Type** A in use at imec.
- Imec ordered **modified Type B of Entegris** (InSync requiring "pockets").
- The latter is now less relevant because of shipping data for Type A ?
- **Gudeng pods**: More recently qualified for NXE3100 by ASML. Modification to InSync EIP gripper scheduled. Hence not used at imec so far.

EUV pod **cleanliness testing** (Entegris Type A)

- 1st test via 20x open/close cycling on InSync + SPARK measurement of blank: no adder for new pod, nor for one **after ~10 months of use**

Shipping results in EUV pods (Entegris Type A)

- 2 blanks, prequalified on SPARK, sent back and forth to US, one site each
  - **Front-side** : both plates have zero adders >250nm
  - **Back-side** : 1st plate has 2 adders >1µm, 2nd plate has 6 such adders

Need to establish shipping by/from mask shop in EUV pod !!
(= removable hard pellicle, assuring FS cleanliness)

CONCLUSIONS

- **Infrastructure** in place for **integrated cleaning**, **automated handling** and **back-side inspection** of NXE reticles (interfaced to scanner via EUV pods).
- **Particle adders by on-site handling are minimized.**
- Very valuable for **learning** about particle contamination of NXE reticles, and **avoiding** it.
- Back-side monitoring helps a lot to trace overlay critical particles, but still **misses capability to differentiate** between those and other (large) detections.
- Infrastructure and procedures (partially) in place ...
  allow to reveal possible particle adders due to the scanner
  (further mitigation by ASML ongoing).
- The next step according to us is ...
  To start using **EUV pods for reticle shipping** from the mask shop.

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* Now at TNO

ASPIRE
INVENT
ACHIEVE

SÜSS MicroTec

nanometrics

imec